

What is claimed is:

- 1 1. A speech communication apparatus comprising:
2 a signal output transducer for receiving a distant signal from a far-end
3 talker and producing acoustic energy of the distant signal;
4 a signal input transducer for producing a near-end signal which may
5 contain a component representing a speech activity of a near-end talker or an
6 acoustic echo component, or both, wherein said acoustic echo component
7 occurs as a result of the distant signal being transmitted through an acoustic
8 echo path from the signal output transducer to the signal input transducer;
9 an echo canceller for producing an echo replica from said distant
10 signal and a residual echo;
11 a residual echo detector for detecting a difference between said near-
12 end signal and said echo replica and supplying the difference as said residual
13 echo to said echo canceller; and
14 a spectral shaper for receiving one of said near-end signal and said
15 residual echo as a first input signal, receiving said echo replica as a second
16 input signal, estimating from the first and second input signals said acoustic
17 echo component when said speech activity is low or zero, and shaping
18 spectrum of said first input signal with the estimated acoustic echo
19 component.
- 1 2. The speech communication apparatus of claim 1, wherein said
2 spectral shaper estimates said acoustic echo component for each of a plurality
3 of subband frequencies of audio spectrum.
- 1 3. The speech communication apparatus of claim 1, wherein said
2 spectral shaper estimates said acoustic echo component from a ratio of said
3 first input signal to said second input signal.

1 4. The speech communication apparatus of claim 1, wherein said
2 spectral shaper estimates said acoustic echo component from a ratio of said
3 first input signal to said second input signal for each of a plurality of subband
4 frequencies of audio spectrum.

1 5. The speech communication apparatus of claim 1, wherein said
2 spectral shaper comprises:
3 means for dividing said first input signal into a first set of subband
4 frequency component signals;
5 means for dividing said second input signal into a second set of
6 subband frequency component signals;
7 a plurality of subband spectral shaping means, each of the subband
8 spectral shaping means receiving a corresponding one of the first set of
9 subband frequency component signals as a first subband signal, receiving a
10 corresponding one of the second set of subband frequency component signals
11 as a second subband signal, producing an estimate of a subband acoustic
12 echo component from the first and second subband signals, and shaping the
13 first subband signal with the estimate of the subband acoustic echo
14 component; and
15 means for combining output signals of said plurality of subband
16 spectral shaping means.

1 6. The speech communication apparatus of claim 5, wherein each
2 of said subband spectral shaping means comprises:
3 a division circuit for producing a ratio of said first subband signal to
4 said second subband signal;
5 a smoother for smoothing said ratio when said speech activity is low
6 or zero;
7 a multiplier for multiplying said second subband signal by said
8 smoothed ratio to produce said estimate of the subband acoustic echo

9 component; and
10 a subtractor for producing a difference signal representative of the
11 difference between the first subband signal and said estimate supplied from
12 said multiplier.

1 7. The speech communication apparatus of claim 6, wherein said
2 smoother includes means for causing said ratio to vary sharply at a rising
3 edge of a transition and vary slowly at a falling edge of the transition.

1 8. The speech communication apparatus of claim 6, wherein said
2 division circuit includes first and second smoothers for smoothing said first
3 and second subband signals, respectively, before said ratio is produced.

1 9. The speech communication apparatus of claim 8, wherein said
2 first smoother includes means for causing said first subband signal to vary
3 sharply at a rising edge of a transition and vary slowly at a falling edge of the
4 transition, and wherein said second smoother includes means for causing
5 said second subband signal to vary sharply at a rising edge of a transition and
6 vary slowly at a falling edge of the transition.

1 10. The speech communication apparatus of claim 5, wherein each
2 of said subband spectral shaping means comprises:
3 a first division circuit for producing a first ratio of said first subband
4 signal to said second subband signal;
5 a second division circuit for producing a second ratio of said second
6 subband signal to said first subband signal;
7 a first smoother for smoothing said first ratio when said speech
8 activity is low or zero;
9 a first multiplier for multiplying the smoothed first ratio by said
10 second ratio;

11 a second smoother for smoothing the output of said first multiplier;
12 a subtractor for subtracting integer 1 from the output of the second
13 smoother; and
14 a second multiplier for multiplying said first subband signal by the
15 output of the subtractor;

1 11. The speech communication apparatus of claim 10, wherein said
2 first smoother includes means for causing said first ratio to vary sharply at a
3 rising edge of a transition and vary slowly at a falling edge of the transition.

1 12. The speech communication apparatus of claim 10, wherein said
2 first division circuit includes first and second smoothers for smoothing said
3 first and second subband signals, respectively, before said first ratio is
4 produced.

1 13. The speech communication apparatus of claim 1, further
2 comprising a harmonics generator for emphasizing harmonics components of
3 said distant signal contained in said echo replica from said echo canceller.

1 14. The speech communication apparatus of claim 1, wherein said
2 echo canceller comprises:
3 means for dividing said residual echo into a first set of subband
4 frequency component signals;
5 means for dividing said distant signal into a second set of subband
6 frequency component signals;
7 an adaptive filter bank for adaptively filtering said second set of
8 subband frequency component signals according to said first set of subband
9 frequency component signals;
10 means for combining output signals of said adaptive filter bank to
11 produce said echo replica; and

12 means for nullifying the first set of subband frequency component
13 signals when said speech activity is high,
14 wherein said spectral shaper comprises:
15 a plurality of subband spectral shaping means, each of the subband
16 spectral shaping means receiving a corresponding one of the first set of
17 subband frequency component signals as a first subband signal, receiving a
18 corresponding one of the output signals of said adaptive filter bank as a
19 second subband signal, producing an estimate of a subband acoustic echo
20 component from the first and second subband signals, and shaping the first
21 subband signal with the estimate of the subband acoustic echo component;
22 and
23 means for combining output signals of said plurality of subband
24 spectral shaping means.

1 15. The speech communication apparatus of claim 14, wherein each
2 of said subband spectral shaping means comprises:
3 a division circuit for producing a ratio of said first subband signal to
4 said second subband signal;
5 a smoother for smoothing said ratio when said speech activity is low
6 or zero;
7 a multiplier for multiplying said second subband signal by said
8 smoothed ratio to produce said estimate of the subband acoustic echo
9 component; and
10 a subtractor for producing a difference signal representative of the
11 difference between the first subband signal and said estimate supplied from
12 said multiplier.

1 16. The speech communication apparatus of claim 15, wherein said
2 smoother includes means for causing said ratio to vary sharply at a rising
3 edge of a transition and vary slowly at a falling edge of the transition.

1 17. The speech communication apparatus of claim 15, wherein said
2 division circuit includes first and second smoothers for smoothing said first
3 and second subband signals, respectively, before said ratio is produced.

1 18. The speech communication apparatus of claim 17, wherein said
2 first smoother includes means for causing said first subband signal to vary
3 sharply at a rising edge of a transition and vary slowly at a falling edge of the
4 transition, and wherein said second smoother includes means for causing
5 said second subband signal to vary sharply at a rising edge of a transition and
6 vary slowly at a falling edge of the transition.

1 19. The speech communication apparatus of claim 14, wherein
2 each of said subband spectral shaping means comprises:
3 a first division circuit for producing a first ratio of said first subband
4 signal to said second subband signal;
5 a second division circuit for producing a second ratio of said second
6 subband signal to said first subband signal;
7 a first smoother for smoothing said first ratio when said speech
8 activity is low or zero;
9 a first multiplier for multiplying the smoothed first ratio by said
10 second ratio;
11 a second smoother for smoothing the output of said first multiplier;
12 a subtractor for subtracting integer 1 from the output of the second
13 smoother; and
14 a second multiplier for multiplying said first subband signal by the
15 output of the subtractor.

1 20. The speech communication apparatus of claim 19, wherein said
2 first smoother includes means for causing said first ratio to vary sharply at a
3 rising edge of a transition and vary slowly at a falling edge of the transition.

1 21. The speech communication apparatus of claim 19, wherein said
2 first division circuit includes first and second smoothers for smoothing said
3 first and second subband signals, respectively, before said first ratio is
4 produced.

1 22. A speech communication apparatus comprising:
2 a signal output transducer for receiving a distant signal from a far-end
3 talker and producing acoustic energy of the distant signal;
4 means for dividing said distant signal into a first set of subband
5 frequency component signals;
6 a signal input transducer for producing a near-end signal which may
7 contain a component representing a speech activity of a near-end talker or an
8 acoustic echo component, or both, wherein said acoustic echo component
9 occurs as a result of the distant signal being transmitted through an acoustic
10 echo path from the signal output transducer to the signal input transducer;
11 means for dividing said near-end signal into a second set of subband
12 frequency component signals;
13 a plurality of subband echo suppressors, each of the subband echo
14 suppressors comprising:
15 an echo canceller for producing an echo replica from a
16 corresponding one of said first set of subband frequency component signals
17 and a subband residual echo;
18 a residual echo detector for detecting a difference between a
19 corresponding one of said second set of subband frequency component
20 signals and said echo replica and supplying the difference as said residual
21 echo to said echo canceller; and
22 subband spectral shaping means for receiving said residual
23 echo as a first subband input signal, receiving said echo replica as a second
24 subband input signal, estimating from the first and second input signals said
25 acoustic echo component when said speech activity is low or zero, and

26 shaping said first subband input signal with the estimated acoustic echo
27 component to produce an output signal of the subband echo suppressor, and
28 means for combining the output signals of said plurality of subband
29 echo suppressors.

1 23. The speech communication apparatus of claim 22, wherein said
2 subband spectral shaping means comprises:
3 a division circuit for producing a ratio of said first subband signal to
4 said second subband signal;
5 a smoother for smoothing said ratio when said speech activity is low
6 or zero;
7 a multiplier for multiplying said second subband signal by said
8 smoothed ratio to produce said estimate of the subband acoustic echo
9 component; and
10 a subtractor for producing a difference signal representative of the
11 difference between the first subband signal and said estimate supplied from
12 said multiplier.

1 24. The speech communication apparatus of claim 23, wherein said
2 smoother includes means for causing said ratio to vary sharply at a rising
3 edge of a transition and vary slowly at a falling edge of the transition.

1 25. The speech communication apparatus of claim 23, wherein said
2 division circuit includes first and second smoothers for smoothing said first
3 and second subband signals, respectively, before said ratio is produced.

1 26. The speech communication apparatus of claim 25, wherein said
2 first smoother includes means for causing said first subband signal to vary
3 sharply at a rising edge of a transition and vary slowly at a falling edge of the
4 transition, and wherein said second smoother includes means for causing

5 said second subband signal to vary sharply at a rising edge of a transition and
6 vary slowly at a falling edge of the transition.

1 27. The speech communication apparatus of claim 22, wherein
2 each of said subband spectral shaping means comprises:
3 a first division circuit for producing a first ratio of said first subband
4 signal to said second subband signal;
5 a second division circuit for producing a second ratio of said second
6 subband signal to said first subband signal;
7 a first smoother for smoothing said first ratio when said speech
8 activity is low or zero;
9 a first multiplier for multiplying the smoothed first ratio by said
10 second ratio;
11 a second smoother for smoothing the output of said first multiplier;
12 a subtractor for subtracting integer 1 from the output of the second
13 smoother; and
14 a second multiplier for multiplying said first subband signal by the
15 output of the subtractor.

1 28. The speech communication apparatus of claim 27, wherein said
2 first smoother includes means for causing said first ratio to vary sharply at a
3 rising edge of a transition and vary slowly at a falling edge of the transition.

1 29. The speech communication apparatus of claim 27, wherein said
2 first division circuit includes first and second smoothers for smoothing said
3 first and second subband signals, respectively, before said first ratio is
4 produced.

1 30. A method of suppressing acoustic echo, comprising the steps of:
2 a) receiving a distant signal from a far-end talker and producing

- 3 acoustic energy of the distant signal from a signal output transducer;
4 b) producing a near-end signal from a signal input transducer
5 which may contain a component representing a speech activity of a near-end
6 talker or an acoustic echo component, or both, wherein said acoustic echo
7 component occurs as a result of the distant signal being transmitted through
8 an acoustic echo path from the signal output transducer to the signal input
9 transducer;
10 c) producing an echo replica from said distant signal and a
11 residual echo, detecting said residual echo between said near-end signal and
12 said echo replica and using the residual echo as a feedback signal to produce
13 said echo replica; and
14 d) receiving one of said near-end signal and said residual echo as a
15 first input signal, receiving said echo replica as a second input signal, and
16 estimating from the first and second input signals said acoustic echo
17 component when said speech activity is low or zero; and
18 e) shaping spectrum of said first input signal with the estimated
19 acoustic echo component.

1 31. The method of claim 30, wherein step (d) estimates said acoustic
2 echo component for each of a plurality of subband frequencies of audio
3 spectrum.

1 32. The method of claim 30, wherein step (d) estimates said acoustic
2 echo component from a ratio of said first input signal to said second input
3 signal.

1 33. The method of claim 30, wherein step (d) estimates said acoustic
2 echo component from a ratio of said first input signal to said second input
3 signal for each of a plurality of subband frequencies of audio spectrum.

1 34. The method of claim 30, wherein step (d) comprises:
2 d₁) dividing said first input signal into a first set of subband
3 frequency component signals;
4 d₂) dividing said second input signal into a second set of subband
5 frequency component signals;
6 d₃) receiving a corresponding one of the first set of subband
7 frequency component signals as a first subband signal, receiving a
8 corresponding one of the second set of subband frequency component signals
9 as a second subband signal, producing an estimate of a subband acoustic
10 echo component from the first and second subband signals, and shaping the
11 first subband signal with the estimate of the subband acoustic echo
12 component; and
13 d₄) combining output signals of said plurality of subband spectral
14 shaping means.

1 35. The method of claim 34, wherein step (d₃) comprises:
2 producing a ratio of said first subband signal to said second subband
3 signal;
4 smoothing said ratio when said speech activity is low or zero;
5 multiplying said second subband signal by said smoothed ratio to
6 produce said estimate of the subband acoustic echo component; and
7 producing a difference signal representative of the difference between
8 the first subband signal and said estimate supplied from said multiplier.

1 36. The method of claim 35, wherein the smoothing step causes said
2 ratio to vary sharply at a rising edge of a transition and vary slowly at a
3 falling edge of the transition.

1 37. The method of claim 35, wherein the ratio producing step
2 includes the step of smoothing said first and second subband signals before

3 said ratio is produced.

1 38. The method of claim 37, wherein the step of smoothing the first
2 and second subband signals causes said first and second subband signals to
3 vary sharply at a rising edge of a transition and vary slowly at a falling edge
4 of the transition.

1 39. The method of claim 34, wherein step (d) comprises:

2 d₁) producing a first ratio of said first subband signal to said second
3 subband signal;

4 d₂) producing a second ratio of said second subband signal to said
5 first subband signal;

6 d₃) smoothing said first ratio when said speech activity is low or
7 zero;

8 d₄) multiplying the smoothed first ratio by said second ratio;

9 d₅) smoothing the multiplied smoothed first ratio;

10 d₆) subtracting integer 1 from the first ratio smoothed by step (d₅)
11 to produce a subtracted signal; and

12 d₇) multiplying said first subband signal by said subtracted signal.

1 40. The method of claim 39, wherein step (d₃) includes the step of
2 causing said first ratio to vary sharply at a rising edge of a transition and vary
3 slowly at a falling edge of the transition.

1 41. The method of claim 39, wherein step (d₁) includes the steps of
2 smoothing said first and second subband signals before said first ratio is
3 produced.

1 42. The method of claim 30, further comprising accentuating
2 harmonics components of said distant signal contained in said echo replica

3 before estimating said acoustic echo component.

1 43. The method of claim 30, wherein step (c) comprises the steps of:
2 dividing said residual echo into a first set of subband frequency
3 component signals;
4 dividing said distant signal into a second set of subband frequency
5 component signals;
6 adaptively filtering said second set of subband frequency component
7 signals according to said first set of subband frequency component signals;
8 combining the adaptively filtered signals to produce said echo replica;
9 and
10 nullifying the first set of subband frequency component signals when
11 said speech activity is high,
12 wherein step (d) comprises:
13 receiving a corresponding one of the first set of subband frequency
14 component signals as a first subband signal, receiving a corresponding one of
15 the adaptively filtered signals as a second subband signal, and producing an
16 estimate of a subband acoustic echo component from the first and second
17 subband signals;
18 shaping the first subband signal with the estimate of the subband
19 acoustic echo component; and
20 combining a plurality of said shaped first subband signals.

1 44. The method of claim 43, wherein the shaping step comprises:
2 producing a ratio of said first subband signal to said second subband
3 signal;
4 smoothing said ratio when said speech activity is low or zero;
5 multiplying said second subband signal by said smoothed ratio to
6 produce said estimate of the subband acoustic echo component; and
7 producing a difference signal representative of the difference between

8 the first subband signal and said estimate of the subband acoustic echo
9 component.

1 45. The method of claim 44, wherein the smoothing step causes said
2 ratio to vary sharply at a rising edge of a transition and vary slowly at a
3 falling edge of the transition.

1 46. The method of claim 44, wherein the ratio producing step
2 comprises the steps of smoothing said first and second subband signals
3 before said ratio is produced.

1 47. The method of claim 46, wherein the steps of smoothing the first
2 and second subband signals cause said first and second subband signals to
3 vary sharply at a rising edge of a transition and vary slowly at a falling edge
4 of the transition.

1 48. The method of claim 43, wherein the shaping step comprises:
2 d₁) producing a first ratio of said first subband signal to said second
3 subband signal;
4 d₂) producing a second ratio of said second subband signal to said
5 first subband signal;
6 d₃) smoothing said first ratio when said speech activity is low or
7 zero;
8 d₄) multiplying the smoothed first ratio by said second ratio;
9 d₅) smoothing the multiplied smoothed first ratio;
10 d₆) subtracting integer 1 from the first ratio smoothed by step (d₅)
11 to produce a subtracted signal; and
12 d₇) multiplying said first subband signal by said subtracted signal.

1 49. The method of claim 48, wherein step (d₃) includes the step of

2 causing said first ratio to vary sharply at a rising edge of a transition and vary
3 slowly at a falling edge of the transition..

1 50. The method of claim 48, wherein step (d₁) includes the steps of
2 smoothing said first and second subband signals before said first ratio is
3 produced.

1 51. A method of suppressing acoustic echo, comprising the steps of:
2 a) receiving a distant signal from a far-end talker and producing
3 acoustic energy of the distant signal from a signal output transducer;
4 b) dividing said distant signal into a first set of subband frequency
5 component signals;
6 c) producing a near-end signal by a signal input transducer,
7 wherein the near-end signal may contain a component representing a speech
8 activity of a near-end talker or an acoustic echo component, or both, wherein
9 said acoustic echo component occurs as a result of the distant signal being
10 transmitted through an acoustic echo path from the signal output transducer
11 to the signal input transducer;
12 d) dividing said near-end signal into a second set of subband
13 frequency component signals;
14 e) producing an echo replica from a corresponding one of said
15 first set of subband frequency component signals and a subband residual
16 echo, detecting the subband residual echo between a corresponding one of
17 said second set of subband frequency component signals and said echo
18 replica and using said subband residual echo as a feedback signal to produce
19 said echo replica;
20 f) receiving said residual echo as a first subband input signal,
21 receiving said echo replica as a second subband input signal, and estimating
22 from the first and second input signals said acoustic echo component when
23 said speech activity is low or zero;

- 24 g) shaping said first subband input signal with the estimated
25 acoustic echo component to produce an output signal; and
26 h) combining a plurality of said output signals.

1 52. The method of claim 51, wherein step (g) comprises the steps
2 of:
3 producing a ratio of said first subband signal to said second subband
4 signal;
5 smoothing said ratio when said speech activity is low or zero;
6 multiplying said second subband signal by said smoothed ratio to
7 produce said estimate of the subband acoustic echo component; and
8 producing a difference signal representative of the difference between
9 the first subband signal and said estimate supplied from said multiplier.

1 53. The method of claim 52, wherein the smoothing step causes said
2 ratio to vary sharply at a rising edge of a transition and vary slowly at a
3 falling edge of the transition.

1 54. The method of claim 52, wherein the ratio producing step
2 includes the steps of smoothing said first and second subband signals before
3 said ratio is produced.

1 55. The method of claim 54, wherein the steps of smoothing said
2 first and second subband signals cause said first and second subband signals
3 to vary sharply at a rising edge of a transition and vary slowly at a falling
4 edge of the transition.

1 56. The method of claim 51, wherein step (e) comprises the steps
2 of:
3 e₁) producing a first ratio of said first subband signal to said second

- 4 subband signal;
5 e₂) producing a second ratio of said second subband signal to said
6 first subband signal;
7 e₃) smoothing said first ratio when said speech activity is low or
8 zero;
9 e₄) multiplying the smoothed first ratio by said second ratio;
10 e₅) smoothing the multiplied smoothed first ratio;
11 e₆) subtracting integer 1 from the first ratio smoothed by step (e₅)
12 to produce a subtracted signal; and
13 e₇) multiplying said first subband signal by said subtracted signal.

1 57. The method of claim 56, wherein step (e₃) causes said first ratio
2 to vary sharply at a rising edge of a transition and vary slowly at a falling
3 edge of the transition.

1 58. The method of claim 56, wherein step (e₁) includes the steps of
2 smoothing said first and second subband signals before said first ratio is
3 produced.

1 59. A spectral shaper for cancellation of noise comprising:
2 means for dividing a first input signal into a first set of subband
3 frequency component signals;
4 means for dividing a second input signal into a second set of subband
5 frequency component signals;
6 a plurality of subband spectral shaping means, each of the subband
7 spectral shaping means receiving a corresponding one of the first set of
8 subband frequency component signals as a first subband signal, receiving a
9 corresponding one of the second set of subband frequency component signals
10 as a second subband signal, producing an estimate of a subband noise
11 component from the first and second subband signals, and shaping the first

12 subband signal with the estimate of the subband noise component; and
13 means for combining output signals of said plurality of subband
14 spectral shaping means.

1 60. The spectral shaper of claim 59, wherein each of said subband
2 spectral shaping means comprises:
3 a division circuit for producing a ratio of said first subband signal to
4 said second subband signal;
5 a smoother for smoothing said ratio when said first input signal is
6 indicative of low or zero speech activity;
7 a multiplier for multiplying said second subband signal by said
8 smoothed ratio to produce said estimate of the subband noise component;
9 and
10 a subtractor for producing a difference signal representative of the
11 difference between the first subband signal and said estimate supplied from
12 said multiplier.

1 61. The spectral shaper of claim 60, wherein said smoother includes
2 means for causing said ratio to vary sharply at a rising edge of a transition
3 and vary slowly at a falling edge of the transition.

1 62. The spectral shaper of claim 60, wherein said division circuit
2 includes first and second smoothers for smoothing said first and second
3 subband signals, respectively, before said ratio is produced.

1 63. The spectral shaper of claim 62, wherein said first smoother
2 includes means for causing said first subband signal to vary sharply at a
3 rising edge of a transition and vary slowly at a falling edge of the transition,
4 and wherein said second smoother includes means for causing said second
5 subband signal to vary sharply at a rising edge of a transition and vary

6 slowly at a falling edge of the transition.

1 64. The spectral shaper of claim 59, wherein each of said subband
2 spectral shaping means comprises:
3 a first division circuit for producing a first ratio of said first subband
4 signal to said second subband signal;
5 a second division circuit for producing a second ratio of said second
6 subband signal to said first subband signal;
7 a first smoother for smoothing said first ratio when said first input
8 signal is indicative of low or zero speech activity;
9 a first multiplier for multiplying the smoothed first ratio by said
10 second ratio;
11 a second smoother for smoothing the output of said first multiplier;
12 a subtractor for subtracting integer 1 from the output of the second
13 smoother; and
14 a second multiplier for multiplying said first subband signal by the
15 output of the subtractor.

1 65. The spectral shaper of claim 64, wherein said first smoother
2 includes means for causing said first ratio to vary sharply at a rising edge of a
3 transition and vary slowly at a falling edge of the transition.

1 66. The spectral shaper of claim 64, wherein said first division
2 circuit includes first and second smoothers for smoothing said first and
3 second subband signals, respectively, before said first ratio is produced.